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Molybdenum Recycling in the United States in 1998

By John W. Blossom

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FLOW STUDIES FOR RECYCLING METAL COMMODITIES IN THE UNITED STATES

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FOREWORD

As world population increases and the world economy expands, so does the demand for natural resources. An accurate assessment of the Nation's mineral resources must include not only the resources available in the ground but also those that become available through recycling. Supplying this information to decisionmakers is an essential part of the USGS commitment to providing the science that society needs to meet natural resource and environmental challenges.

The U.S. Geological Survey is authorized by Congress to collect, analyze, and disseminate data on the domestic and international supply of and demand for minerals essential to the U.S. economy and national security. This information on mineral occurrence, production, use, and recycling helps policymakers manage resources wisely.

USGS Circular 1196, "Flow Studies for Recycling Metal Commodities in the United States," presents the results of flow studies for recycling 26 metal commodities, from aluminum to zinc. These metals are a key component of the U.S. economy. Overall, recycling accounts for more than half of the U.S. metal supply by weight and roughly 40 percent by value.

Charles G. Groat
Director

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CONVERSION FACTORS

Multiply	By	To obtain
	Length	
kilometer (km)	0.6214	mile
inch (in.)	25.4	millimeter
	Volume	
cubic foot (ft^3)	0.02832	cubic meter
	Mass	
gram (g)	0.03527	ounce avoirdupois
kilogram (kg)	2.205	pound avoirdupois
kilogram (kg)	32.1507	troy ounce
metric ton (t, 1,000 kg)	1.102	short ton (2,000 pounds)
troy ounce (troy oz)	31.10	gram
	Pressure	
pound force per square inch	6.895	kilopascal
atmosphere (atm)	101.3	kilopascal

For temperature conversions from degrees Celsius (°C) to degrees Fahrenheit (°F), use the following:

$$°F = (1.8 \times °C) + 32$$

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ABSTRACT

This report describes the flow of molybdenum in the United States in 1998 with emphasis on the extent to which molybdenum was recycled. Molybdenum was mostly recycled from products of molybdenum-bearing steels and superalloys; some molybdenum products were recovered specifically for their high molybdenum content. In 1998, 8,000 metric tons of molybdenum were estimated to have been recycled, and the recycling rate was calculated to be 33 percent with a recycling efficiency of about 30 percent.

INTRODUCTION

The materials flow of molybdenum, as shown in figure 1, describes molybdenum supply and demand factors for the United States in 1998; the figure shows the extent of molybdenum recycling1 and aids in identifying recycling trends. Knowledge of recycling trends is increasingly important because use of scrap promotes conservation of natural resources and enhances the sustainability of primary production for a cleaner environment. Definitions of specialized terms used in characterizing recycling of metals are given in the appendix. Most data used in this report are derived from U.S. Bureau of Mines and U.S. Geological Survey Minerals Yearbooks. Other estimates, such as that for old and new scrap generated, are based on these data. Some figures, such as unrecovered old scrap, are remainders.

Molybdenum is a refractory metallic element used principally as an alloying agent in cast irons, steels, and superalloys to enhance hardenability, strength, toughness, and wear and corrosion resistance. Primarily added in the form of ferromolybdenum or molybdic oxide, it is frequently used in combination with chromium, columbium (niobium), manganese, nickel, tungsten, or other alloy metals to achieve desired metallurgical properties. The versatility of molybdenum has assured it a significant role in contemporary technology and industry, which increasingly require materials that are serviceable under ever higher stresses, over greater temperature ranges, and in more-corrosive environments. Not only does molybdenum find significant usage as a refractory metal, but also in numerous chemical applications, which include catalysts, lubricants, and pigments. The variety of uses for molybdenum materials, few of which afford acceptable substitutions, has resulted in a demand that is expected to grow at a greater rate than most other ferrous metals. Figure 1 shows the domestic flow of molybdenum in 1998 with the flow of recycled molybdenum shown in detail.

[1]Definitions for selected words are found in the Appendix.

DISTRIBUTION OF MOLYBDENUM

Almost all molybdenum is recovered from low-grade deposits that contain the mineral molybdenite (MoS_2). Deposits mined primarily for molybdenum provide from 65 to 70 percent of U.S. output and about 45 percent of world output; the remainder is obtained mainly as a byproduct from mining large, low-grade porphyry copper deposits. Molybdenum ores generally grade from 0.2 to 0.5 weight percent molybdenite; copper ores from which byproduct molybdenum is recovered contain from 0.02 to 0.08 weight percent molybdenite.

Distribution of molybdenum reserves and productive capacity is concentrated in a few countries of the world. In 1998, world mine output was an estimated 135,000 metric tons (t) (molybdenum contained in concentrate), of which the United States, China, and Chile provided 80 percent; an estimated 10 percent of world output came from Canada and Mexico. These same five countries possess about 85 percent of the estimated 12 million metric tons (Mt) of molybdenum in the world reserve base. The reserve base for the top four countries, by contained molybdenum, is United States, 5,400,000 t; Chile, 2,500,000 t; China, 1,000,000 t; and Canada, 910,000 t. Mexico estimates its reserve base to be 230,000 t. These five countries are expected to continue to be the principal mine producers in the 21st century. Although exploration for new sources is likely to be successful in other areas, these five countries probably have the greatest potential for future additions to reserves and, ultimately, to mine output (Blossom, 2001).

As a result of the concentration of production capacity, international trade in molybdenum materials consists primarily of exports from the United States, China, and Chile to industrialized nations that lack mine production. The major importers are the countries of Western Europe and Japan.

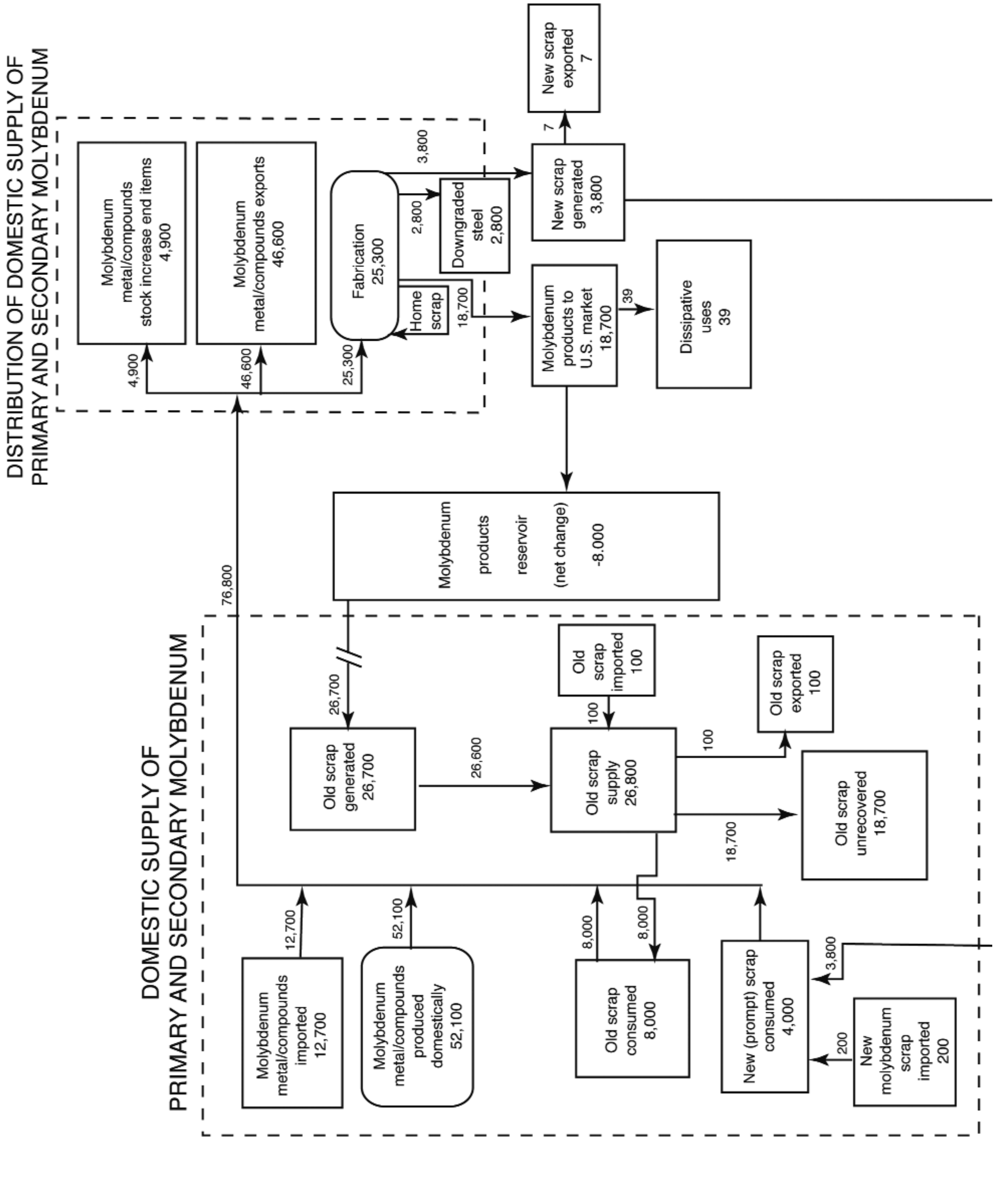

Figure 1. U.S. molybdenum materials flow in 1998. Values are in metric tons contained molybdenum.

Table 1. Salient statistics for U.S. molybdenum scrap in 1998.
[Values in metric tons of contained molybdenum, unless otherwise specified]

Old scrap:	
Generated[1]	26,700
Consumed[2]	8,000
Consumption value[3]	$70 million
Recycling efficiency[4]	30 percent
Supply[5]	26,800
Unrecovered[6]	18,700
New scrap consumed[7]	4000
New-to-old-scrap ratio[8]	33:67
Recycling rate[9]	33 percent
U.S. net imports of scrap[10]	190
Value of U.S. net imports of scrap	$1.8 million

[1]Molybdenum content of products theoretically becoming obsolete in the United States in 1998. It excludes dissipative uses.

[2]Molybdenum content of products which were recycled in 1998.

[3]Unit value of contained molybdenum in molybdenum oxide was used in calculating total value of contained metal in scrap.

[4](Old scrap consumed plus old scrap exported) divided by (old scrap generated plus old scrap imported plus any old scrap stock decrease or minus any old scrap stock increase).

[5]Old scrap generated plus old scrap imported plus old scrap stock decrease.

[6]Old scrap supply minus old scrap consumed minus old scrap exported minus old scrap stock increase.

[7]Including prompt industrial scrap but excluding home scrap.

[8]Ratio of quantities consumed, expressed as a percentage ratio.

[9]Fraction of the molybdenum supply that is scrap on an annual basis. It is defined as consumption of old plus consumption of new scrap divided by apparent supply (see appendix); measured in weight and expressed as a percentage.

[10]Trade in scrap is judged to be about equally divided between old and new scrap. Net exports are exports of scrap minus imports of scrap.

The United States has exported about one-half of its mine output in recent years, mostly as concentrate or oxide, and currently (1998) supplies about 45 percent of the molybdenum consumed in other market-economy countries. Because U.S. producers have a viable molybdenum scheme made up of a strong reserve base and mining and marketing plans, the United States is expected to continue as a leading supplier of molybdenum to the world market (Blossom, 2002).

Salient molybdenum scrap statistics are based on the molybdenum content of catalyst, steel, and superalloy scrap. In 1998, about 26,700 t of molybdenum was contained in molybdenum-bearing old scrap available to be recycled. About 8,000 t of molybdenum, which was valued at about $70 million, was recycled (table 1). The old scrap recycling efficiency was calculated to be about 30 percent, and the recycling rate was about 33 percent. Molybdenum contained in new scrap consumed was about 4,000 t.

GEOLOGIC OCCURRENCE OF MOLYBDENUM

The average crustal abundance of molybdenum is 1 to 2 parts per million (ppm). Molybdenum does not occur in nature in its free or native state, but is found only chemically combined with other elements. MoS_2, which is a lead-gray metallic mineral that characteristically occurs in thin, tabular, commonly hexagonal plates and is also disseminated as fine particles, is the only molybdenum mineral of commercial importance. It has a specific gravity of 4.6 to 4.7, a hardness of 1 to 1.5, and a greasy feel and soils the fingers. Superficially, it resembles graphite, for which it has commonly been mistaken (Blossom, 1985; King and others, 1973).

Wulfenite ($PbMoO_3$), which is a molybdate of lead, is a metallic mineral of variable color. The mineral has a resinous or adamantine luster, a hardness of 2.75 to 3, a specific gravity of 6.5 to 7, and a white streak. It generally occurs in well-formed crystals, chiefly square and tabular. Deposits are found almost entirely in veins, mostly in the oxidized parts of lead deposits. Occurrences of wulfenite are numerous, but none are of economic importance. Powellite-scheelite [Ca (Mo, W) O_4] is a calcium molybdate-tungsten solid solution series; tungsten may substitute for up to 10 percent molybdenum. Primarily hydrothermal, powellite and scheelite occur in veins and skarns and are not alteration products of molybdenite. Powellite-scheelite is nearly always impure; it has a hardness of 3.5 and a specific gravity of 4.3 and varies in color from dirty white to gray, straw yellow, greenish yellow, pale greenish blue, and brown. Powellite is found with scheelite, and this association helps identify the mineral because it fluoresces a golden yellow. Ferrimolybdite ($Fe_2Mo_3O_{12}\cdot 8H_2O$) is a very soft, hydrous mineral of distinctive canary-yellow color; it is an oxidation product of molybdenite and pyrite. It occurs as fine, needlelike crystals and has a hardness of 1.5 and a specific gravity of 2.99 to 4.5. Other molybdenum minerals include chillagite, eosite, ilsemannite, jordisite, koechlinite, and lindgrenite (King and others, 1973).

TYPES OF DEPOSITS

Molybdenum deposits are of five geologic types—porphyry or disseminated deposits, which include stockworks and breccia pipes in which metallic sulfides are dispersed through relatively large volumes of hydrothermally altered and fractured rock; contact-metamorphic zones and tactite bodies of silicated carbonate-bearing rocks, such as aplite dikes and pegmatites; bedded deposits in sedimentary rocks; carbonate-bearing shale, dolostone, and limestone, adjacent to intrusive granitic rocks; and quartz veins.

The first three genetic-type deposits are hydrothermal in origin and represent nearly all the identified molybdenum resources currently mined in the world. In hydrothermal deposits, metallic minerals are precipitated from high-

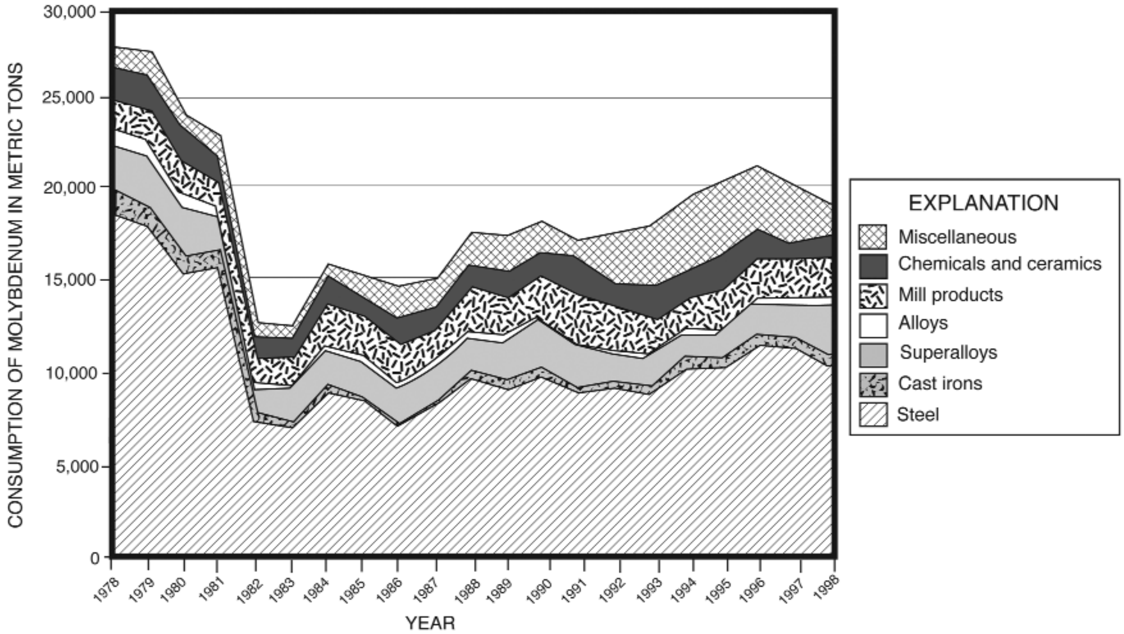

Figure 2. U.S. molybdenum consumption, by end-use sector, from 1978 through 1998.

temperature aqueous fluids either by changes in temperature and pressure or by evaporation of the liquid. Minerals are deposited in the cavities, cracks, or interstices of the host rock. Intrusive rocks, with which the metallic minerals are genetically related, range from intermediate to felsic in composition and include: porphyritic intrusions, dioritic, granitic, and quartz monzonitic composition (Bookstrom, 1999). Metallization commonly takes place in the host intrusive and in the surrounding or overlying country rock. The Climax and the Henderson deposits in Colorado and the Questa deposit in New Mexico are examples of such hydrothermal molybdenum stockwork deposits.

Most of the porphyry copper deposits in the Western United States contain small quantities of molybdenite disseminated with the copper minerals through large bodies of granite rock. The chief minerals are chalcopyrite and chalcocite; pyrite and small amounts of other sulfides, which include molybdenite, also are in the composition. In addition, minor amounts of other base-metal minerals, specular hematite, fluorite, and secondary silicate minerals are present. Chalcocite replaces chalcopyrite and pyrite in the zone of secondary enrichment. The copper-to-molybdenum ratio ranges from about 10 to 1 to perhaps 150 to 1, and generally increases inward and downward within the porphyry copper system.

Small quantities of molybdenite are widely distributed in lime-silicate deposits along the contacts between granitic intrusive rocks and lime-rich sedimentary rocks. Molybdenite is commonly associated with bismuthinite, copper sulfides, or scheelite in zones of silicated limestone near granitic intrusive rocks. The only domestic production from this type of mineralization has been as a byproduct from the Pine Creek tungsten deposit in California. The mineral deposit originated by replacement of the carbonate rock.

Magmatic hydrothermal fluid also is involved in formation of aplites and pegmatites. Aplites form by “pressure quenching” of magma in response to rapid loss of agueous fluid. In pegmatites, crystals and fluid coexist. Growth of large crystals is prompted by slow crystal nucleation and rapid ionic diffusion to crystal growth sites. In aplites and pegmatites, MoS_2 deposition involves interactions among crystals, magma, and magmatic-hydrothermal fluid. Pegmatites are coarsely crystalline and consist almost exclusively of quartz and feldspar. Molybdenite occurs as an accessory mineral, and the individual crystals are generally large and usually euhedral. Many pegmatites contain apatite, beryl, cassiterite, columbite, ilmenite, magnetite, rutile, wolfram, and zircon. The average grade of these types of deposits is low; hence, they are not important potential producers of molybdenum. Pegmatite-type deposits that contain disseminated molybdenum associated with bismuth were mined in Val d’ Or and Preissac in Quebec, Canada (King and others, 1973).

Molybdenum minerals occur in coal, phosphorite, shale, lignitic sandstone, and some arkosic sandstone. A small quantity of molybdenum was recovered from uraniferous lignites in North Dakota and South Dakota until 1968 when output from these sources ceased.

Molybdenum is obtained from primary molybdenum mines and byproduct copper and tungsten mines. Countries that produced molybdenum in 1998 were Armenia, Canada, Chile, China, Iran, Kazakhstan, Mexico, Mongolia, Peru, the Republic of Korea, Russia, the United States, and Uzbekistan (Blossom, 2001).

SOURCES OF MOLYBDENUM FROM SCRAP

Molybdenum is recycled as a component of ferrous scrap, which comprises home, new, and old scrap. Home, or mill scrap is generated within the steel mill during production of iron and steel. Old scrap includes metal articles that have been discarded after serving a useful purpose. Because of the wide variety of chemical and physical characteristics, old scrap often requires significant preparation. The molybdenum component is identified, but in most cases, the scrap is selected for other elements that it contains. If additional molybdenum is required in the melt in making steel, then primary ferromolybdenum or molybdenum oxide, which are products derived from ore, are added.

When the valuable metals or compounds have been recovered, molybdenum catalysts are changed to an environmentally acceptable state so that catalysts do not become solid waste. These metals may be used again in other end uses or reused in catalysts.

Pure and alloyed molybdenum metal and compound scrap from chemical plants, furnaces, trimmings from fabrication processes, and unuseable fabricated items compose new scrap and reenter the flow and through the melt process.

Alloy and stainless steel are major sources of molybdenum-bearing scrap. Although molybdenum is not recovered separately from scrap steel and superalloys that contain it, recycling of these alloys is significant, and the molybdenum content is reused. Some of the molybdenum content that is recycled, however, may be effectively downgraded in alloys where it is tolerated, but not essential.

OLD SCRAP GENERATED

As shown in figure 1, the starting point for molybdenum scrap flow through processing is old scrap generated, which is the amount of molybdenum that became obsolete in 1998. The old scrap supply available to industry is estimated to be 26,700 t; the estimate was based on the lifetimes of products in which molybdenum is used, which ranged from 10 to 60 years, with an estimated average of 20 years. Some scrap is lost to the environment, and some is unrecoverable. In 1998, industry used an estimated 8,000 t of old scrap; 100 t was exported, and 18,700 t was unrecovered. Figure 2 shows changes in end-use patterns from 1978 to 1998; these changes will result in changes in the mix of end uses of old scrap generated in the future.

NEW SCRAP

New scrap consumed in 1998 was estimated to range from 3,800 to 4,000 t, of which 200 t was imported and the rest, domestically generated. The new-scrap-to-old-scrap-consumption ratio during 1998 was 33 to 67. New scrap consisted mainly of trimmings from fabrication processes, such as stamping and recycling of unuseable fabricated items. New scrap may also be produced in the manufacture of another commodity product, such as the tungsten filament used in light bulbs. In its manufacture, the filament is twisted around a tiny molybdenum rod. The rod is then dissolved in acid and shipped for recycling as a sludge.

DISPOSITION OF MOLYBDENUM SCRAP

Old scrap consists mainly of molybdenum-bearing steel, which includes alloy, carbon, and stainless steel, that may have been used in many applications. The steel grades with the highest percentages of molybdenum are in the alloy and stainless steel categories. The highest volume of production, however, is in carbon steel. This scrap, which is derived from demolition of bridges, buildings, and other structures, junked cars, and manufacturing equipment, is sold to scrap dealers. Molybdenum catalysts, sometimes in relatively pure form and sometimes contained in sludges, usually are sold by chemical processors to small specialized catalyst-recycling plants.

RECYCLING EFFICIENCY FOR OLD SCRAP

The relation between the amount of scrap that is theoretically available for recycling and what is actually recovered and reused is called recycling efficiency. Old scrap recycling efficiency during 1998 was estimated to be 30 percent. Because data were not available, stock changes were not taken into account. Recycling efficiency is not expected to increase significantly because molybdenum scrap competes with new materials, which are readily available and tend to suppress some molybdenum-bearing scrap prices, thereby limiting scrap recycling and, consequently, recycling efficiency. Additionally, much molybdenum-bearing scrap, such as stainless steel scrap, is usually purchased for other metal content, so its collection usually is dependent on the prices of other commodities, such as chromium and nickel.

INFRASTRUCTURE OF THE MOLYBDENUM SCRAP INDUSTRY

Steel mills and foundries that require ferrous molybdenum-bearing scrap and superalloy melt shops that require pure molybdenum scrap are supplied by brokers and scrap collectors and processors (Fenton, 2001). Other types of scrap from spent catalyst and metal-laden solutions, such as those generated in the production of light bulb filaments, must be processed to comply with environmental requirements. Brokers bring scrap buyers and sellers together on a scrap transaction and receive a fee for this service. Consumers use brokers to procure scrap; processors use their services to market their scrap. Brokers purchase scrap for a particular client buyer without having storage or processing facilities or sometimes without any certainty of finding a buyer who will offer a favorable price and profit. The scrap recycling infrastructure in the United States causes its recycling rate to be equal to and, in most cases, exceed that of other industrialized countries, and the rate is much higher than that of lesser developed countries.

Amlon Metals Inc., which was headquartered in New York, N.Y., and was founded about 1950, provided reclamation services worldwide. The company recycled about 200,000 t per year of metal-bearing materials and provided documents, sampling, transport, and certification of recycling materials. Their focus was on about 10 metals, which included molybdenum, and catalysts where a significant portion of their business. Hi-Temp Specialty Metals in Willingboro, N.J., processed chips, electrodes, molybdenum turnings, and wire. International Metals Reclamation Company, Inc. (INMETCO) in Ellwood City, Pa., converted about 63,000 t of molybdenum-bearing secondary material, which included electric-arc furnace (EAF) dust, spent catalyst, mill scale, and grinding swarf, into about 24,000 t of iron-chromium-nickel ingots with 1.1 percent molybdenum content. The molybdenum recycled from this source alone was about 264 t (Cassidy, 2001).

PM Recovery in New Castle, Pa., specialized in processing molybdenum-bearing nickel and cobalt-based grindings, turnings, and off-specification ingot. Kalumetals, Inc. in Latrobe, Pa., used a batch-process furnace to produce molybdenum oxide. Langeloth Metallurgical in Pittsburgh, Pa., used some secondary material in its molybdenum oxide roasters (Cassidy, 2001).

PROCESSING OF MOLYBDENUM SCRAP

By using a variety of equipment, scrap dealers collect and process scrap into a physical form and chemical composition that can be consumed. The type and size of equipment they use depends on the types and volume of scrap available in the area and the requirements of their customers. The largest and most expensive piece of equipment is the shredder. The shredder can fragment discarded objects into fist-sized pieces; shredded metals, glass, rubber, and plastic are segregated before shipment. Hydraulic shears, which have cutting blades of chromium-nickel-molybdenum alloy steel for hardness, slice heavy pieces of plate, chemical piping, and structural steel into chargeable pieces. Baling presses are used to compact scrap into manageable bundles, thereby reducing scrap volume and shipping costs. Scrap dealers must carefully sort the scrap they sell, and consumers must purchase scrap that does not contain unacceptable levels of undesirable elements.

Old and new molybdenum scrap consumed or recycled during 1998 was about 12,000 t (4,000 t new and 8,000 t old). Appliances, bicycles, and other molybdenum-bearing steel were shredded for recycling. More than 1,500 scrap yards processed steel from construction and demolition sites by shearing, shredding, and baling.

Fabrication of new products produces new scrap that is relatively chemically and physically clean and of known chemical composition. For this reason, most scrap consumers prefer new scrap to old scrap. Preparation of new scrap is usually limited to cutting, cleaning, and baling prior to rapid transport back to the consumer for recycling. Processes used may include calcining, drying, leaching, precipitation, and various means of separation. Some processing may be subcontracted for sludgelike material, catalysts, dusts, grindings, and solutions. Hi-Temp Specialty Metals processed chips, electrodes, molybdenum turnings, and wire by crushing and abrading the material in a ring mill to remove oxide films in preparation for vacuum melting by others. A roasting process was used by INMETCO and Langeloth Metallurgical at their Ellwood City and Pittsburgh, Pa., facilities (Cassidy, 2001).

SUMMARY AND OUTLOOK FOR MOLYBDENUM RECYCLING FLOW

Consumption of molybdenum, and the growth or decline of the scrap industry, depends directly on the health of the specialty and carbon steelmaking industries. Most regions of the world will see a marked increase in steel consumption during the next 5 years, according to the International Iron and Steel Institute (American Metal Market, 2000). In the United States, a steadily increasing population and a growing economy in the long term should assure that the demand for steel products, and the scrap used to make them, will also increase. Steel and scrap consumption will increase as Federal funding of highway and bridge projects increases and will require structural and reinforcement bar products. The use of steel framing is increasing in construction of multifamily developments, retirement homes, and single-family residences. A thriving industry is also dependent on plentiful inexpensive energy. As energy costs rise, the demand for some steel applications may be affected, but demand for pipe and tubular goods used in the oil and gas industry will increase for new drilling and refining projects (Fenton, 2001).

The EAF consumes mostly scrap to make steel. The EAF contribution to total steel production has risen dramatically during the past 30 years, and the amount of EAF-produced steel should continue to increase, perhaps at a rate of 4 percent per year during the next decade (Steel Times International, 2000). The EAF may be the primary steel production method in the world by 2010 (Forster, 1999). The use of the EAF has increased in minimills from small units limited in use for specialty steel production to the large-capacity furnace used to produce a wide range of steels, which includes flat product sheet and plate, long product bars, structural shapes, tubulars, and wire (Recycling Today, 1998). From 1998 through 2000, EAF steel comprised nearly 50 percent of all steel produced in the United States (Fenton, 2002).

The availability of scrap, and operating and capital cost advantages, have made EAF growth possible. Relocations and establishments of new minimills in areas of increasing population growth and manufacturing activity in the Southern States and the Western States and away from the traditional “Rust Belt” States have, to a large extent, satisfied demand for construction steel products and products used by the oil and gas industry. The EAF process is flexible in its material requirements, and plants can also operate with considerable flexibility in making various products depending on market requirements (Worden, 2000). EAF steelmaking will continue to grow because of the capital and operating cost advantages relative to those of the basic-oxygen furnace (BOF), the increasingly wide range of steel products that it makes, and its environmental cleanliness. The use of the EAF is the most effective way of reducing carbon dioxide emissions, and less energy is needed to melt scrap than to smelt ore. Use of EAFs will increase as minimills are built, and EAFs may replace more operating BOFs (Katrak and others, 1999).

Ferrous alloy scrap will remain the most important raw material used. Increasing availability of direct-reduced and hot-briqueted iron from domestic producers because of the increasing need for low-residual element feedstocks for the production of high-quality flat steel and special-bar-quality steels required to compete in the higher end markets will be a factor in dampening this trend.

Recycling of molybdenum-bearing scrap will continue to be dependent on the markets for the principal alloy metals of iron, nickel, and chromium, in which molybdenum is often found. Although large quantities of molybdenum will continue to be consumed in downgraded form in steelmaking, molybdenum will continue to be recycled in this manner. As long as the value of molybdenum remains relatively low, scrap metal is not likely to be sought for its molybdenum content. Therefore, recycling rates and efficiency are not likely to change significantly in the near term.

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APPENDIX—DEFINITIONS

apparent consumption. Primary plus secondary production (old scrap) plus imports minus exports plus adjustments for Government and industry stock changes.

apparent supply. Apparent consumption plus consumption of new scrap.

dissipative use. A use in which the metal is dispersed or scattered, such as paints or fertilizers, making it exceptionally difficult and costly to recycle.

downgraded scrap. Scrap intended for use in making a metal product of lower value than the metal product from which the scrap was derived.

home scrap. Scrap generated as process scrap and consumed in the same plant where generated.

new scrap. Scrap produced during the manufacture of metals and articles for both intermediate and ultimate consumption, including all defective finished or semifinished articles that must be reworked. Examples of new scrap are borings, castings, clippings, drosses, skims, and turnings. New scrap includes scrap generated at facilities that consume old scrap. Included as new scrap is prompt industrial scrap—scrap obtained from a facility separate from the recycling refiner, smelter, or processor. Excluded from new scrap is home scrap that is generated as process scrap and used in the same plant.

new-to-old-scrap ratio. New scrap consumption compared with old scrap consumption, measured in weight and expressed in percent of new plus old scrap consumed (for example, 40:60).

old scrap. Scrap including (but not limited to) metal articles that have been discarded after serving a useful purpose. Typical examples of old scrap are electrical wiring, lead-acid batteries, silver from photographic materials, metals from shredded cars and appliances, used aluminum beverage cans, spent catalysts, and tool bits. This is also referred to as postconsumer scrap and may originate from industry or the general public. Expended or obsolete materials used dissipatively, such as paints and fertilizers, are not included.

old scrap generated. Metal content of products theoretically becoming obsolete in the United States in the year of consideration, excluding dissipative uses.

old scrap recycling efficiency. Amount of old scrap recovered and reused relative to the amount available to be recovered and reused. Defined as (consumption of old scrap (COS) plus exports of old scrap (OSE)) divided by (old scrap generated (OSG) plus imports of old scrap (OSI) plus a decrease in old scrap stocks (OSS) or minus an increase in old scrap stocks), measured in weight and expressed as a percentage:

$$\frac{\text{COS} + \text{OSE}}{\text{OSG} + \text{OSI} + \text{decrease in OSS or} - \text{increase in OSS}} \times 100$$

old scrap supply. Old scrap generated plus old scrap imported plus old scrap stock decrease.

old scrap unrecovered. Old scrap supply minus old scrap consumed minus old scrap exported minus old scrap stock increase.

primary metal commodity. Metal commodity produced or coproduced from metallic ore.

recycling. Reclamation of a metal in usable form from scrap or waste. This includes recovery as the refined metal or as alloys, mixtures, or compounds that are useful. Examples of reclamation are recovery of alloying metals (or other base metals) in steel, recovery of antimony in battery lead, recovery of copper in copper sulfate, and even the recovery of a metal where it is not desired but can be tolerated—such as tin from tinplate scrap that is incorporated in small quantities (and accepted) in some steels, only because the cost of removing it from tinplate scrap is too high and (or) tin stripping plants are too few. In all cases, what is consumed is the recoverable metal content of scrap.

recycling rate. Fraction of the apparent metal supply that is scrap on an annual basis. It is defined as (consumption of old scrap (COS) plus consumption of new scrap (CNS)) divided by apparent supply (AS), measured in weight and expressed as a percentage:

$$\frac{\text{COS} + \text{CNS}}{\text{AS}} \times 100$$

scrap consumption. Scrap added to the production flow of a metal or metal product.

secondary metal commodity. Metal commodity derived from or contained in scrap.